REFRIGERATION REVIEW

REFRIGERATION SYSTEM EFFICIENCY

I would like to talk about the age-old subject of large, industrial refrigeration system efficiency. There is a lot of confusion going around about what kind of systems are the most efficient. First of all, a single stage system operating on freezers CANNOT be as thermodynamically efficient as a two-stage system. The blow-by on screw compressors can be significant and there's no good way to provide subcooling of the liquid. At best, a side-port in a screw compressor at an "arbitrary" location would be the only way to try to get some subcooling. Sometimes people think screw compressors are the latest technology, but screw compressors – horsepower for horsepower – are never as efficient as reciprocating compressors. The only reason we use them is if we need a compressor larger than 250 HP. The clearances in a piston/ring type compressor is about .02 while the clearance in a screw compressor as a minimum would be at best in the order of .04 to .06.

My first observation of the vast difference in compression efficiency of screw compressors occurred in the early development of screw compressor packages when I installed a Dunham Bush unit which was on a Frick package and later added the same model Dunham Bush but on an FES package. I was rather amazed to see one compressor out pump the other compressor by a 10-pound suction pressure difference. I observed the same thing between a 250 HP Vilter 440 reciprocating compressor and a 250 HP screw compressor, it was also a

Dunham Bush variety, except the difference in that case was a net 30% difference and although the screw had recently been overhauled, we later found out the screw had a .030 clearance. While more lobes, such as with the GEA compressors, and ball and roller bearings have helped maintain closer clearances such as in the Frick design, the wear from the capacity slide valve and variable VI permitting blow-by will decrease efficiency. A side-port cavity I've been told decreases efficiency by 5%. We have found over time the maintenance cost of a good quality reciprocating machine like a Vilter 440 series is far less than the maintenance and replacement of twin-screw compressors, and when you consider the power cost it's a no-brainer. Also, it's worth noting that the Vilter mono-screw machine costs significantly less to maintain than a twin screw. Another interesting point is if you look at some of the old Frick HDI charts and calculate the horsepower per ton, you will see the efficiency improves as the bore of the piston increases in size. It doesn't take Einstein to realize that small piston machines have less efficiency because the clearance volume becomes a higher percent of the compression chamber. This is another reason why small Freon compressors will never match industrial central system efficiency. Although the screw compressors are highly reliable, their efficiency suffers the same way twin screws suffer from blow-by.

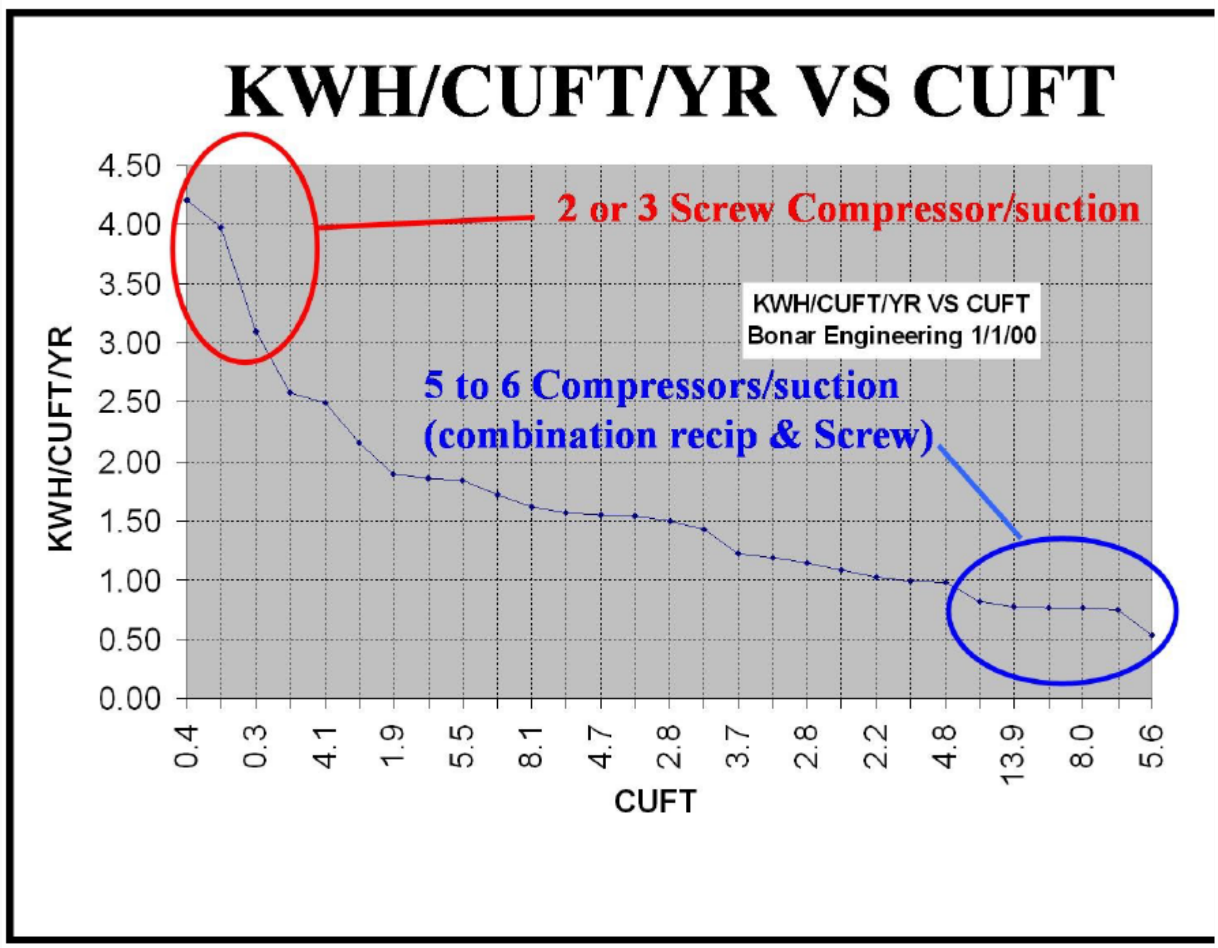
One more point, is the case told to me by a man working for Sullair air compressor division. He had just come back from an installation which involved replacing (4) 125 HP reciprocating air compressors with (4) 125 HP screw compressors. The four screw compressors could not provide as much air as the 4 reciprocating compressors, and a 5th screw compressor had to be added to provide the same CFM of air. So, you can conclude from that that screw compressors are 20% less efficient. If you consider a difference of 100 KW 24/7 that would equal $673,000 a year. That would cover a lot of maintenance costs.

A direct expansion (DX) system CANNOT be as efficient as a recirculating system. Direct expansion systems waste 30% of the evaporator coil surface just to make the DX system work. It should go without saying that commercial split systems are only cost effective on small refrigerated facilities, generally 250,000 cubic feet or less. Although, when process loads are involved, small cascade central systems would be effective as well.

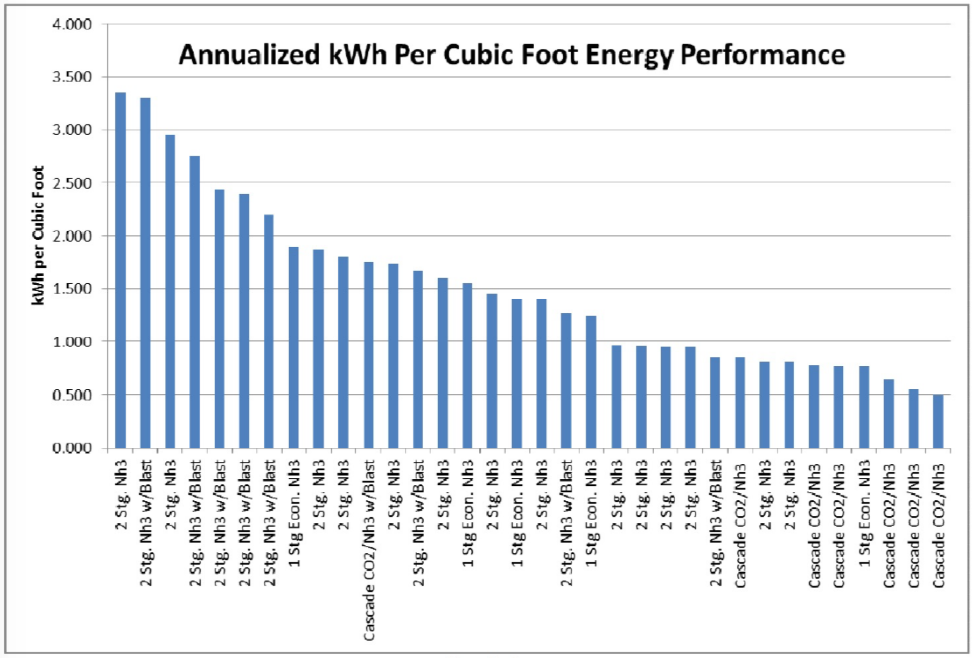
Years ago, I got a call from John Rotelle, who was building a high-rise automated facility outside Philadelphia. He said, “Hank I got four bids from refrigeration contractors, and the horsepower varies from 400 HP to 700 HP. Which one is correct?” Well, refrigeration contractors are not known to design efficient refrigeration systems; they normally design them with minimum compressors, and with variable frequency drive (VFD) screw compressors.

Let me pause and explain my disdain for VFDs, it’s two-fold. First, at best, VFDs consume 8% to 10% more energy than a high efficiency motor, and second, when the VFD operates two compressors at 1000 rpm, when they’re designed for 3600 rpm, you lose another 10% to 15% efficiency. The most efficient refrigeration systems in the world may not only use screw compressors, but will also use reciprocating compressors, as can be seen in the graph below. Systems that use multiple compressors (screw or reciprocating) are the most efficient. Publix Super Markets, a grocery chain in the Southeast and one of the most efficiently-run perishable food distributors in the world, and Sanderson Farms both have the most efficient refrigeration systems in North America. Lineage Logistics, one of the largest public refrigerated warehousing companies in the world, did a survey a couple of years ago of their facilities to see which facility was the most efficient, and the one we designed and built in Macon, GA was determined to be one of their most efficient facilities. The reason is simple – it has cyclable reciprocating compressors. (If you don’t need it, turn it off.)

In addition to the design of the refrigeration system, the design of the refrigerated building the system serves is just as important. We have seen it over and over again, especially from people that come to us from developing third world countries, where an architect or engineer that has never designed a refrigerated building proposes a box-in-a-box, typically used in small walk-in boxes. The fallacies are many-fold. The primary one is that the ceiling panels will eventually fill up with ice and fall and become a serious hazard. We have seen it time and time again where regardless of how well you try to seal the panels, air and water molecules vibrating at the speed of sound will penetrate the cracks and crevices and eventually permeate the insulation and accumulate enough weight in ice and water to cause the supporting system to fail. A properly designed refrigerated structure will have a conventional roof slope that, with planning, can complement the air movement in the room and pipeline slope, which can then be placed outside the refrigerated areas. With recirculating systems, the pipelines need to slope like sewer lines, and the roof configuration and slope can be a very important part of that. This is a big advantage from a servicing perspective, and with CO_2 you only have one valve that will require maintenance. I've said it time and time again – the refrigeration designer needs to influence the geometry of the roof slope and relative heights of the different areas, such as shipping docks, making sure the pipeline is adequately sloped and that the machinery room configuration complements the design. I've seen a few cases where the architect and structural engineer designed the building without considering refrigeration requirements, which can cause some major challenges in an efficient and safely-operated refrigeration system.



Freezer Energy Consumption Comparison by Facility



Refrigeration System Energy Consumption Comparison by Facility